Computer Vision-Based Framework for Supporting the Mobility of the Visually Impaired

Wafa Elmannai and Dr. Khaled Elleithy
Department of Computer science and Engineering
University of Bridgeport, Bridgeport, CT

Abstract

This poster presents an intelligent framework that includes several types of sensors embedded in a wearable device to support the visually impaired (VI) community. The proposed work is based on an integration of sensor-based techniques and a computer vision-based in order to introduce an efficient and economical visual device. The 98% accuracy rate of the proposed sequence is based on a wide detection view that used two camera modules. In this framework, we use several computer vision algorithms including Oriented FAST and Rotated BRIEF (ORB), k-nearest neighbors (KNN), Random sample consensus (RANSAC), and K-mean. However, the novelty of this work is the obstacle avoidance approach that is based on the image depth and fuzzy control rules. The results of our real time experiments emphasize that the proposed collision avoidance approach is able to aid the VI users in avoiding 100% of detected objects.

Motivations

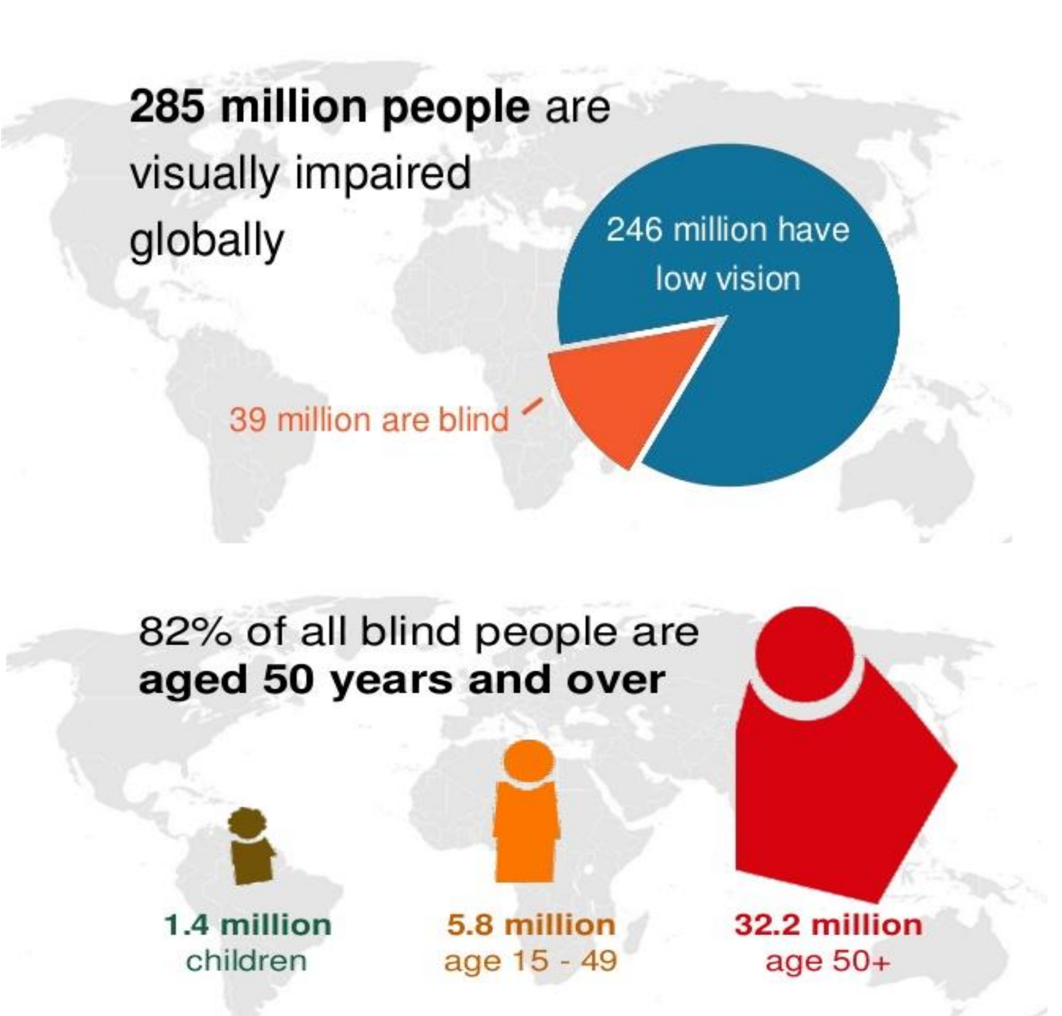

Figure 1: Statistical study for the population of visually impaired worldwide

Proposed Fusion of Sensor-Based Data using Computer Vision

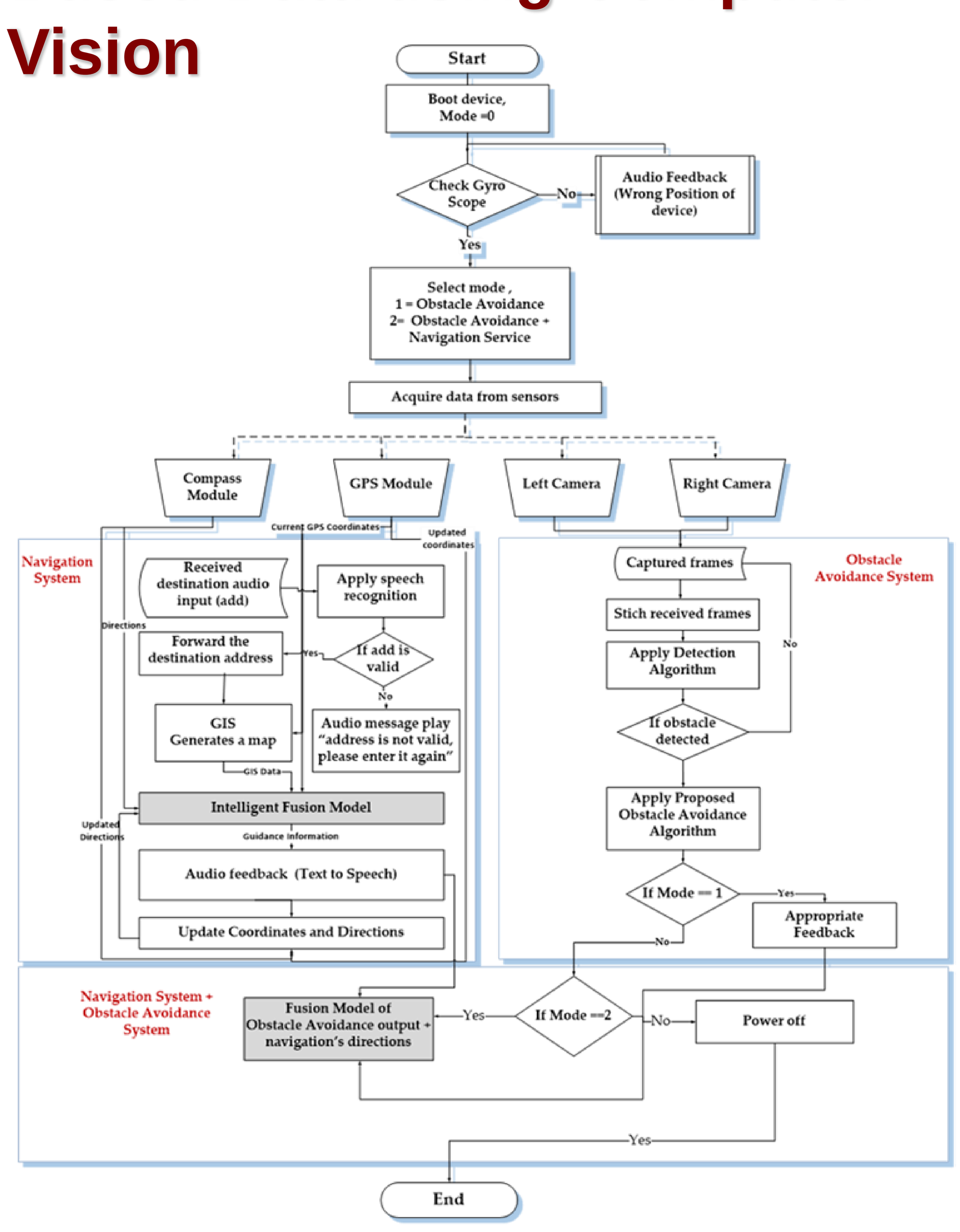

Figure 2: Flowchart of the proposed data fusion algorithm using multiple sensors

Proposed Distance Measurement Method

A. Static/Dynamic Obstacle Detection Algorithm

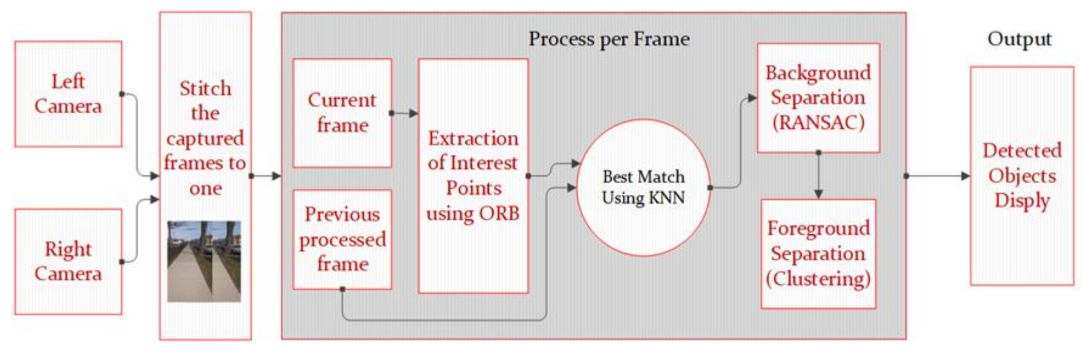

Figure 3: The block diagram of the static/dynamic object detection algorithm

B. Obstacle Avoidance Region

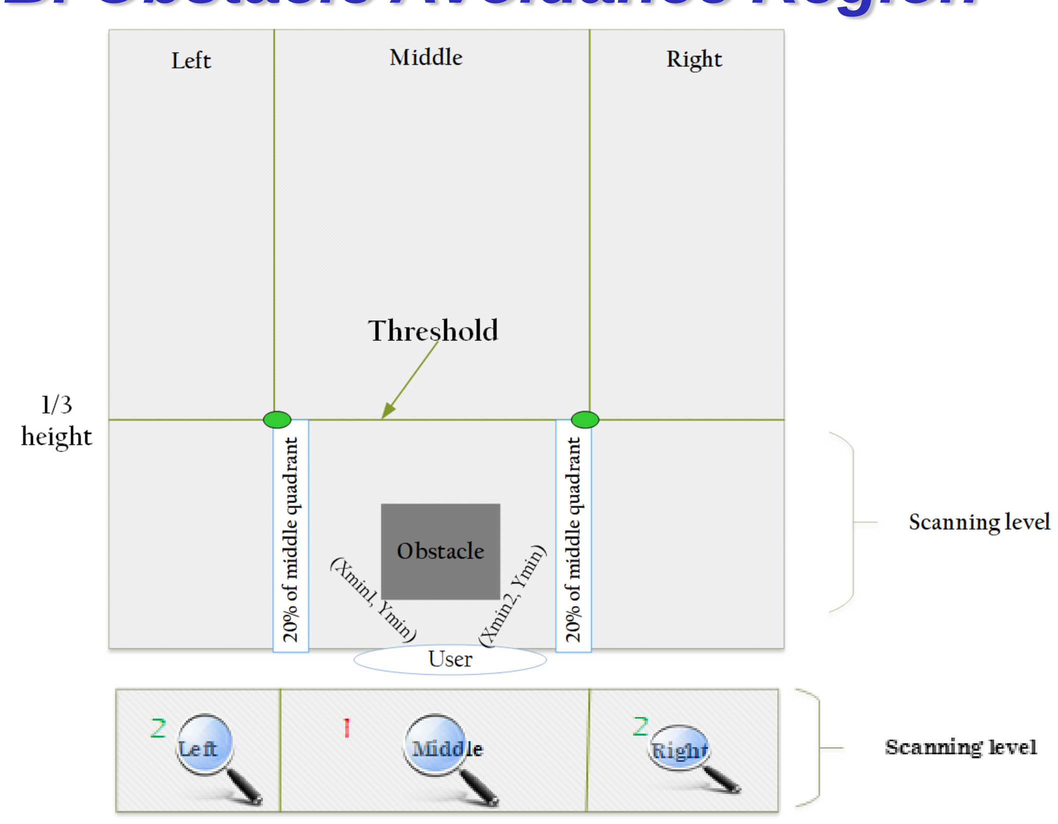

Figure 4: The proposed distance measurement method for object avoidance

C. Fuzzy Logic Controller Design for Obstacle Avoidance

The input variables for the proposed system are seven inputs, which are {Obs Range,User Position, Obs Left, Obs 20%LeftMid, Obs Middle, Obs 20%RightMid, and Obs Right}. The output is the feedback that the user needs for a path to the endpoint.

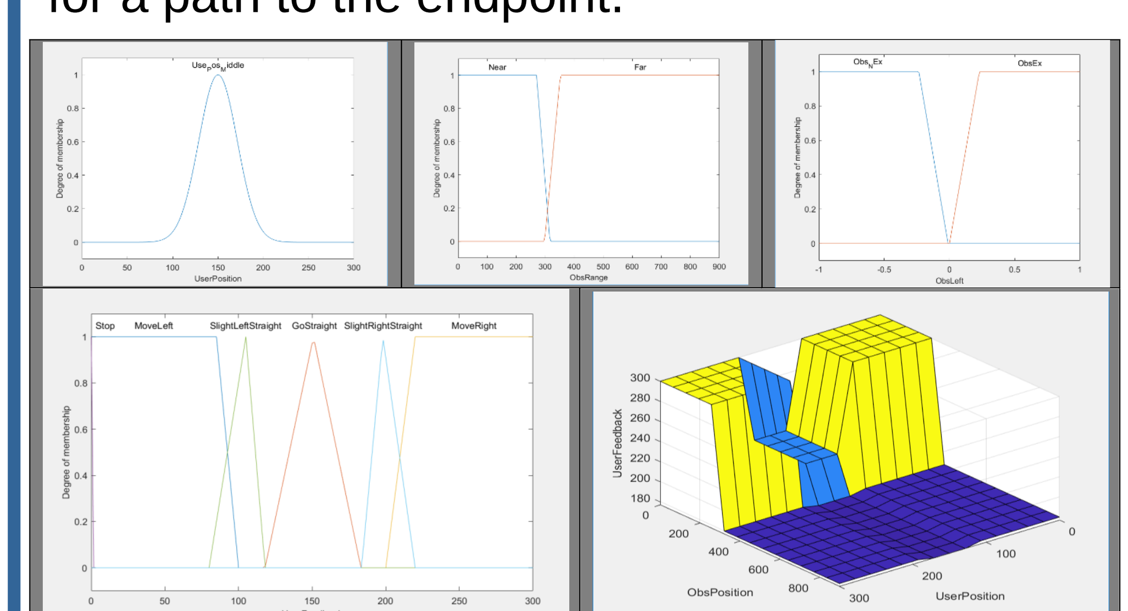

Figure 5: The Fuzzy logic structure for obstacle avoidance system; input, output member functions and surface viewer for designed system

Hardware Prototype

GHI components were used to design the device. .Net Gadgeteer software was used to implement the proposed algorithm on the device [3]. The hardware design is composed of two camera, compass, GPS, gyroscope module, audio, microphone, and wi-fi module.

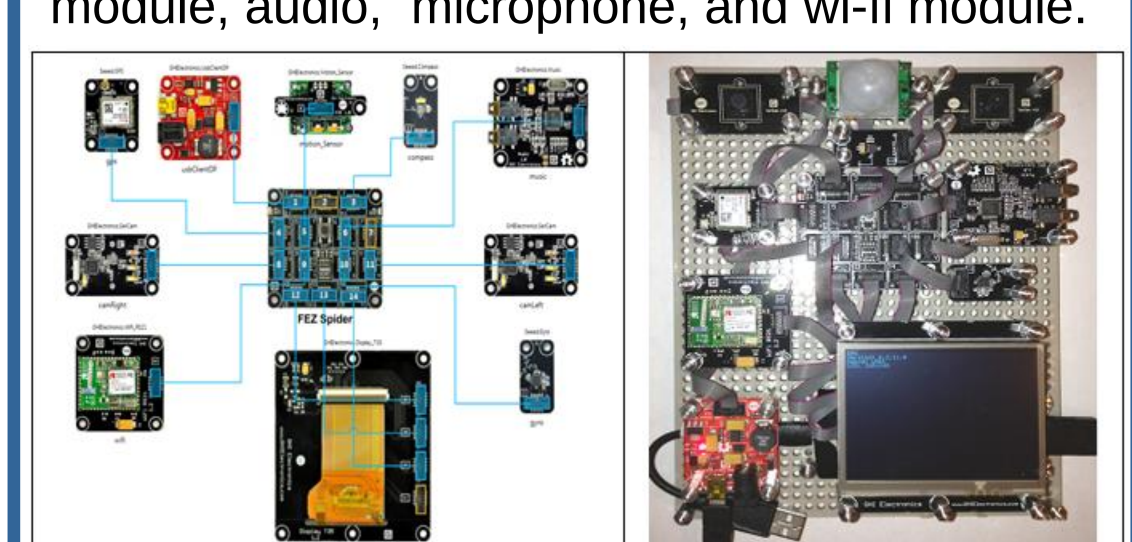

Figure 6: Designed device and hardware architecture

Performance Evaluation Results, Comparison and Discussion

Video	Average Number of Frames	Average Number of Objects per Video	Average Number of Obstacles per Video	Average Number of Detected Objects per Video	Average Number of Detected Obstacles per Video	Accuracy per Video For Detected Objects	Accuracy per Video for Detected Obstacles	Processing Time per Frame
Video #1	288	36	20	32	20	88.89%	100.00%	17.5 ms
Video #2	237	15	15	15	15	100.00%	100.00%	18 ms
Video #3	862	50	-	44	-	88.32%	-	36 ms
Video #4	590	35	17	34	17	97.14%	100.00%	26.66 ms
Accuracy of the Detection Algorithm = 96.40%								

Table 1: Accuracy and processing time results of real-time scenarios to evaluate the proposed framework

No. of Videos	Average Number of Frames per Video	Detection Rate for Detected Objects	Detection Rate for only Detected Obstacles	True Positive Rate	False Negative Rate
30	700	Worst: 85.71% Average: 96.72% Best: 100%	100.00%	98.36%	1.64%

Table 2: Detection rate for the adapted data set

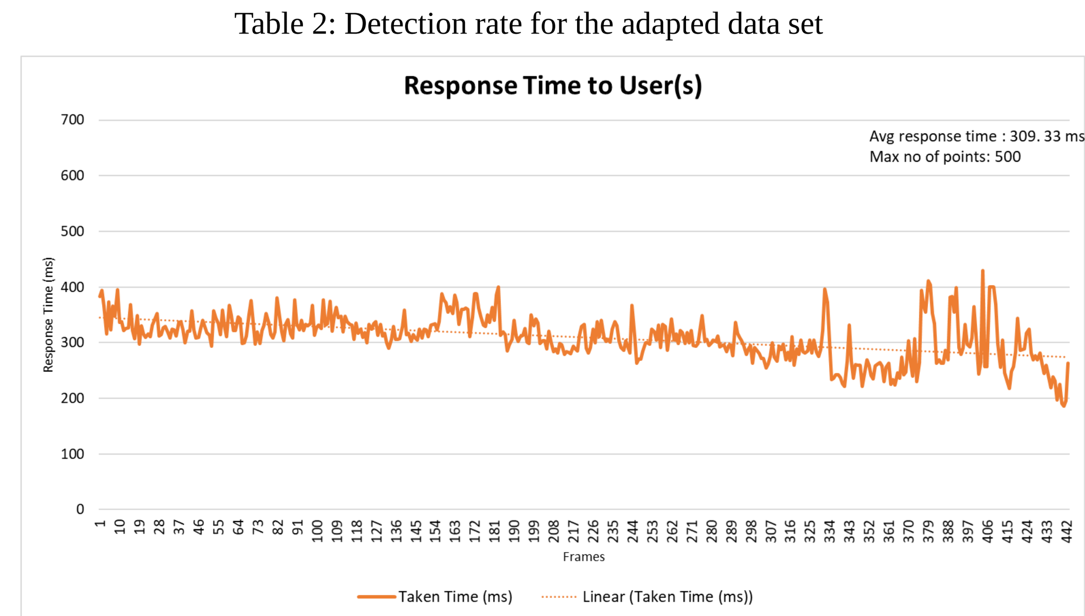

Figure 7: The cost of the proposed obstacle avoidance approach as a time function

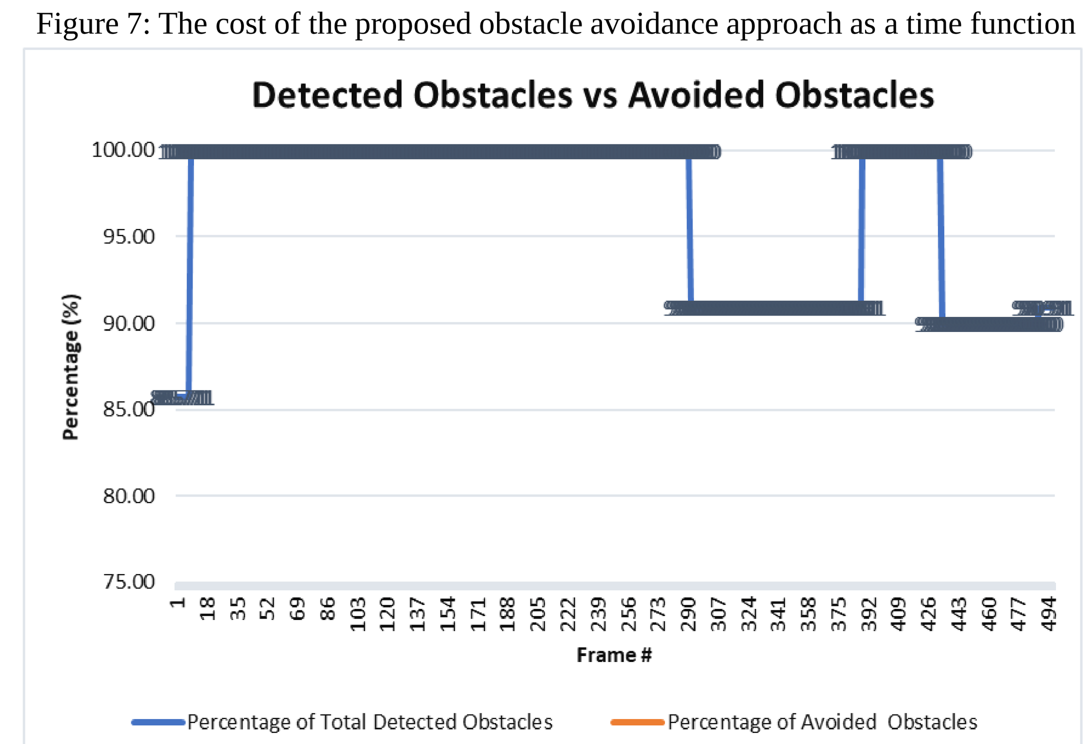

Figure 8: The performance evaluation of the collision avoidance system

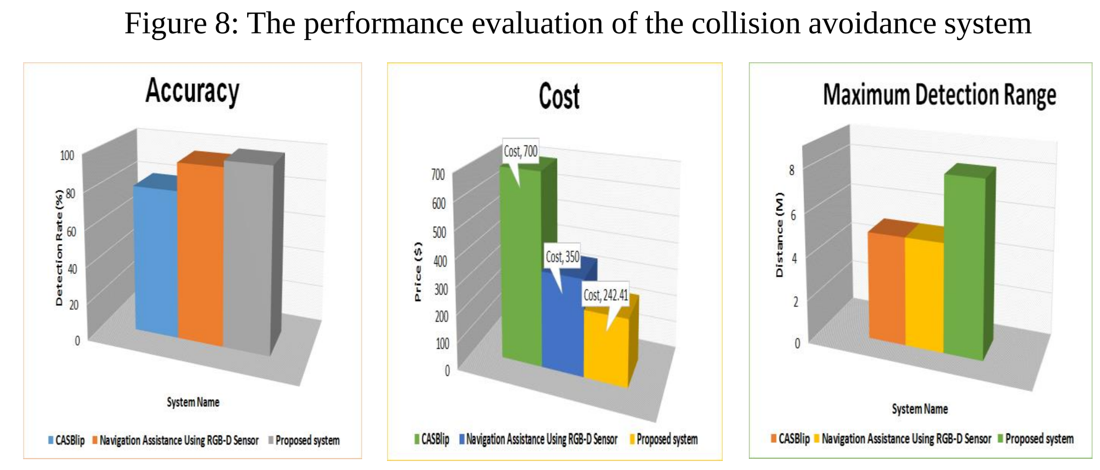

Figure 9: Comparison and analysis of the best current methods and proposed method

Conclusion

The system was implemented using a .NET Gadgeteer-compatible mainboard and modules from GHI Electronics. In addition, we introduce a novel obstacle avoidance algorithm based on the image depth and fuzzy logic. The output is divided into six membership functions that are based on the fused input variables and controlled by 18 fuzzy rules. The system has been deployed and tested in real-time scenarios.

However, the proposed obstacle avoidance system can be implemented in different applications such as automotive applications, self-driving vehicles, and military applications.

References

[1] Wafa Elmannai and Khaled Elleithy, "A Highly Accurate and Reliable Data Fusion Framework for Guiding the Visually Impaired," IEEE ACCESS, accepted, 2017.
[2] Elmannai, Wafa, and Khaled Elleithy. "Sensor-based assistive devices for visually-impaired people: current status, challenges, and future directions." Sensors 17.3 (2017): 565.
[3] Wafa Elmannai and Khaled Elleithy, "A Novel Obstacle Avoidance System for Guiding the Visually Impaired through the use of Fuzzy Control Logic," 3rd Workshop on Accessible Devices and Services (ADS), 15th IEEE Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, USA, 12-15 January 2018.